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SINGLE COLUMN PYROTECHNIC DELAY

Wayne W. Smith

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In the past, rocket assisted artillery projectiles used dual column pyrotechnic delays as a mechanism for igniting the rocket motor. The development of a single column pyrotechnic delay is discussed. Design methodology and results of testing are also discussed.

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The successful implementation of a single column pyrotechnic delay would not be possible without the professionalism and foresightedness of Mr. Nelson Bowman (Talley Defense Systems) and Mr. Tony Fabiano (Ferrulmatic Inc.)

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INTRODUCTION

This report is an attempt to describe the methodology used in developing a reliable pyrotechnic delay for the M913 cartridge. No in-depth discussion of the fundamental chemical relationships or theories are given due to the availability of other reports and books on this subject.

BRIEF HISTORY

The U.S. military has been developing gun launched rocket assisted projectiles for several decades. Although rockets have been used for centuries, gun launched systems were developed to overcome inherent inaccuracies of the pure rocket system.

The M913 cartridge (fig. 1) is one in a line of rocket assisted projectiles developed by the U.S. Army for its 105-mm artillery weapon system. The 105-mm artillery system is not the only system to have a rocket assisted projectile developed for it. The 155-mm and the 8 in. artillery weapons also have rocket assisted projectiles. For all three systems the rocket assisted projectiles are primarily high explosive warheads.

Concerning the 105-mm system, the first rocket assisted projectile was the M548 (fig. 2). This projectile came into Army inventory during the early 1970's. The delay for this projectile is a dual column pyrotechnic delay with a 16 sec burn time and the delays used for the 155-mm system and the 8 in. system are dual column pyrotechnic delays with a 7 sec burn time.

The basic reasons for the delay in rocket motor ignition are to enhance range, precision, and safety. Most rocket assisted projectiles are launched at some angle greater than 45 deg, usually around 50 deg. When the projectile attains an angle with a horizon of 45 deg, the rocket motor ignites. Theoretically, an ignition angle of 45 deg provides an equal amount of thrust in the horizontal and vertical vectors. The precision of a rocket assisted projectile is enhanced when a delayed ignition is used because the launch instabilities are allowed to dampen out before the rocket is ignited. The safety aspect of a delayed ignition is that the ignition of the rocket motor takes place well away from the weapon; therefore, the gun crew will not be exposed to the motor gasses or the ejected delay.

THE M913 PROGRAM

The M913 program was initiated during the mid-1980's. Its development was in response to an Army requirement for an extended range projectile to be used in the M119 weapon. The M119 weapon is a lightweight howitzer that would eventually replace the older M101 and M102 howitzers now in the inventory (table 1).

In comparison, the M548 projectile can be used in the M119 gun but is restricted to the M176 propellant charge. The M913 can be used with the M67 charge (cartridge will be designated M927) and the M229 charge (table 2). The reason for having two different charges is that the M67 is a zonable propellant charge (the muzzle velocity of the projectile can be adjusted) and the M229 is a nonadjustable maximum propellant charge (the muzzle velocity of the projectile is increased to the maximum).

There are some advantages in using the M913 over the M1 or the M548. A large increase in lethality and range are but a few (table 3).

When the research and development effort started on the M913, a deliberate attempt was made to incorporate an electronic delay into the projectile. The overall program was divided into several different phases (fig. 3). The electronic delay functioned exceptionally well through the initial engineering phase of the program but experienced difficulties during the advanced engineering phase. The problems with the electronic delay proved to be insurmountable given the tight schedule for completion of the program.

In an effort to forestall a major program slippage, a pyrotechnic delay was implemented as a replacement for the electronic delay. This decision, at the time, seemed to be the best possible solution due to the fact that the M548 projectile used a pyrotechnic delay successfully throughout its development and production cycles.

M913 DELAY PROBLEM

The pyrotechnic delay that was initially used on the M913 was for the most part identical to the M548 delay (fig. 4). The minor differences between the M548 delay and the M913 are that the M913 housing had shouldered washers, while the M548 had unshouldered washers.

The chemical composition used in the M913 was identical to that which was used in the M548 (table 4). This original combination of chemical constituents produced a delay time of 16 sec with a standard deviation of .35 sec.

The reasons behind the incorporation of a stepped washer were to reduce the variations in column height, enhance the crimp strength, and prevent any preloading of the delay column due to the crimping operation.

During the latter half of 1988, Talley Defense Systems, Mesa, Arizona, started production of M913 delay composition. Three different compositions were mixed; 34 pbw (parts by weight), 36 pbw, and 38 pbw. These three were chosen because the M548 used 35 pbw tungsten content and the thought was that the M913 should use approximately the same content.

On February 28, 1989, the three delay compositions were tested at Yuma Proving Ground (YPG), Yuma, Arizona. The test results showed that the three mixes bracketed the required delay time of 16 sec (table 5). This self imposed requirement of 16 sec comes from a compromise of delay time and maximum range for the XM927 and the M913 (fig. 5). After the test of the three delay mixes a graph was generated (fig. 6) and the ideal composition determined by interpolating the curve. The results of the interpolation showed that a Tungsten content of 36.75 pbw should get a delay time of approximately 16.00 sec.

At this point a new mix was manufactured at Talley Defense and the Tungsten content was 36.75 pbw. On April 21, 1989, this delay composition was tested at YPG (table 6). The results of this test were quite perplexing. The delay time turned out to be 13.24 sec with a standard deviation of 0.619. This strange behavior was attributed to an unknown anomaly with Talley's manufacturing process. In order to prevent a major slippage to the program schedule, Lonestar Army Ammunition Plant would manufacture all subsequent delay compositions.

The sequence of tests performed during this April time frame highlighted the delay problem but a new problem was encountered; a pyrotechnic delay, which was in the off mode, had functioned.

Besides trying to overcome the delay composition problem, the M913 also had to overcome a delay functioning problem. Various tests were conducted to ascertain the cause of this inadvertent functioning. The data proved that a delay would function in the off mode if the cap was not seated properly. When the cushion material was changed from silicone to EPDM rubber it was demonstrated that even an improperly seated cap would not cause the delay to function. The cap problem seemed to be solved but the delay problem had to be addressed.

Lonestar Army Ammunition Plant was now tasked with producing a mix of delay composition consisting of 36.75 pbw Tungsten. On June 30, 1989, the Lonestar delay composition was tested at YPG and the results proved to be disturbing. The delay time was now 11.15 sec with a standard deviation of .191 (table 7). This delay time was in no way comparable to the delay time generated by the Talley 36.75 pbw composition. This shift in the average delay time was attributed to different constituent batches. The various components used in the mix were not made by the same manufacturer nor were they manufactured at the same time.

Lonestar would now be tasked with producing three new mixes based on the 36.75 pbw test data. The three mixes chosen were 31.0 pbw, 32.5 pbw, and 34.0 pbw Tungsten content.

Lonestar produced the three new batches and shipped them to Talley for loading. On August 12, 1989, these batches were evaluated at YPG and the results showed a

shift in the curve to a longer delay time (table 8). For a tungsten content of 31.0, 32.5, and 34.0 the delay times were 25.05, 22.90, and 19.23 sec, respectively.

In an effort to bracket the 16.0 sec delay time, Lonestar was now tasked with producing a 35.1 pbw and a 36.0 pbw composition. The following month the two compositions were ready for evaluation at YPG. The test results of the two compositions were 16.82 sec for the 35.1 pbw mix and 13.72 sec for the 36.0 pbw mix (table 9).

As stated previously, the ideal situation for delay material production is to define the composition curve with three or more test mixes and then interpolate the final or ideal composition mix from this curve. All of the test data up until now showed that the curve was continually shifting and; therefore, to define the ideal mix was an impossible task. In a final attempt to produce a 16.0 second delay, Lonestar was now tasked with producing a composition of 35.5 pbw tungsten. This final mix was ready for loading at Talley at the end of October 1989 (table 10).

Also, as a last ditch effort, Talley Defense was instructed to load some delays with a mixture of pellets. This mixture was a combination of 35.1 pbw and 36.0 pbw compositions. This combination of pellets approach has been attempted in the past and was used in the production of the M548.

The technique used in this combination of pellets approach is first to assume that all compositions burn in a linear manner and then use a combination of pellets that will give the ideal delay interval. From table 11 one can determine that the ideal combination is 4 pellets of 35.1 pbw composition combined with 3 pellets of 36.0 pbw composition.

When combining compositions one should never alternate the pellets because the results will be erratic at best; therefore, first one composition is loaded and then the second composition is loaded. Also, one rule of thumb is to load the slower burning composition into the housing and the faster burning composition last. This sequence is used to ease the transfer of ignition between the two compositions.

Yuma Proving Ground tested both the 35.2 pbw composition as well as the combination delay on November 7, 1989 (table 12). The 35.2 pbw composition produced a delay time of 16.5 sec with a standard deviation of .50 sec. Both delay mixes produced an adequate mean delay time but the standard deviations showed a somewhat erratic reliability problem.

It was decided, at this point in the program, to finish the advance engineering portion of the M913 program using the 36.0 pbw composition. Using this composition would allow the program to continue while providing more time to investigate this delay problem.

SINGLE COLUMN DELAY INVESTIGATION

Engineering Testing

While the advanced engineering portion of the M913 was proceeding, an effort was initiated to find an alternative to the dual column delay. After numerous discussions with Talley Defense Systems and the Naval Surface Warfare Center, it was decided to investigate a single column pyrotechnic delay (fig. 7).

The investigation would begin by using as many parameters of the dual hole design for the single column design (table 13). The pyrotechnic materials would remain the same but their quantity would change and the hole depth of the housing would vary. This varying of the hole depth was a new procedure for the Army. In the past, the hardware was fixed and numerous compositions were manufactured until the required delay time was met for a given column length. At this time, Talley possessed five batches of delay composition leftover from the M785 program; these compositions ranged from a tungsten content of 42 pbw to 49 pbw. It was decided to mix and match hole depth and composition until the right delay time was achieved.

The first single column pyro test took place on 9 March 1990, at YPG. These first delays, of which there were only two, used a column length of 2.75 in. and a tungsten content of 42 pbw. The delay time produced was 30.01 sec with a standard deviation of 1.86 sec (table 14).

The second delay test was executed on 31 March 1990 and these delays utilized a tungsten content of 48 pbw with a 2.75 in. column. The delay time produced was 27.00 sec with an acceptable standard deviation of 0.14 sec (table 15).

At this juncture of the single column delay program, a decision was made to reduce the hole depth because the 48 pbw composition, which is a very fast burner, could not meet the 16 sec delay time requirement. The hole depth in the delay housing was reduced to 1.753 in. and at the same time the 47.5 pbw composition was chosen to be used. Of all the M785 delay compositions, the 49 pbw and 47.5 pbw batches were in greatest supply.

On 10 May 1990, the third iteration of delay testing was accomplished. The 1.753 in. hole depth delays produced a delay time of 15.87 sec and a standard deviation of .18 sec (table 16). This combination of hole depth and composition met the delay time requirement of 16.0 sec.

It was now decided to experiment with varying the hole diameter of the delay while holding the column length a constant. Two types of housings were manufactured one with a .313 in. (5/16) diameter hole and the other with a .375 in. (3/8) diameter hole. This experiment was instigated by a concern that the performance of a pyrotechnic delay is very sensitive to heat transfer. More specifically, the transfer of

heat between the column and the metal housing. If the ideal pyrotechnic delay burns down the center of its column, then it would stand to reason that a large diameter column would provide some insulation against heat transfer. All of the tooling for the large diameter assemblies were sealed up versions of the standard .25 in. diameter tools.

The only precautionary measure taken with the larger hole delays was to use the same consolidation pressure as used on the .25 in. diameter delays (table 17). The consolidation force needed for the 3/8 in. diameter housing is extremely high and at the time this was the maximum that Talley could achieve with their presses.

The testing of the larger hole delays was accomplished on 21 June 1990. Three different types of delays were tested and the results indicate that the 5/16 in. hole was far superior to the 3/8 in. hole (table 18).

Upon completion of the large hole testing the emphasis of the M913 program was to focus on schedule and therefore any further testing of a nonstandard hole diameter column was not considered.

A retest of the standard .25 inch diameter single column delay was to take place on 26-27 July 1990. Two groups of ten delays were tested; ten delays on the 26th and nine delays on the 27th (table 19). The data from this test turned out to be thoroughly confusing. One lot of delays tested on two different days produced opposite results, the delay times were different and the associated standard deviations were also different. In conjunction with this test, two groups of delays would be tested on 1 August 1990, one group at 145°F, and one group at -50°F (table 20). The data from the hot and cold tests followed what was when the delays were tested. The hot delays produced a fast time and the cold delays produced a slow time as compared to the 70°F delays. This increase in the standard deviation of the .25 in. diameter single column delay would now turn the investigation in another direction.

The M913 program was under a considerable amount of pressure to type classify (validate through testing that the cartridge design was safe, met all its performance requirements, and was ready for production). The single column pyro design used what is known as a counterbored washer and it was felt that going back to an uncounterbored washer might be a good approach to eliminate the unacceptable standard deviations (fig. 8).

All of the single hole delay housings left in inventory were modified to the uncounterbored configuration by machining off the top of the delay housing. In all over 130 pcs were modified (fig. 9). These delays were used to accomplish the firing tables tests of the M913 with some success, although a trend of 1 delay in 10 was considered to be an outlier. A list of the firing table test data is shown (table 21). The firing table delays used the 47.5 pbw Tungsten composition.

Upon completion of the firing tables testing it was decided to perform a matrix of tests to sort-out and possibly solve the delay outlier problem. Five different configurations of the single column delay were manufactured by Talley Defense and then shipped to YPG for testing (Table 22).

On 25 August 1990, the eight delays that were assembled without washers were tested (table 23). The four uncounterbored delays functioned while the counterbored delays had three no-functions. This test seems to indicate that the counterbored configuration is highly sensitive to the gun environment.

The configurations S002, S003, and S004 were tested on 30 August 1990. Lot S002 was used to obtain data for the M927 configuration (table 24). One interesting note is that this delay configuration test with the M927 produces an acceptable delay burn time but, when tested with the M913, the burn time becomes inconsistent.

The S003 and S004 lots were tested with the M913 projectile. Lot S003 still produced inconsistent burn times (table 25) while lot S004 produced consistent burn times (table 26). The results from S004 were encouraging and, in reality, the only change was the increase in tungsten content from 47.5 pbw to 49 pbw.

To confirm the safety and reliability of the single column delay, a safety test and ballistic test were performed during the month of September. The safety test projectiles used delay lots S003 and S004, while the ballistic test used lot S005 and the engineering samples. The ten delays from lot S005 and the engineering samples are basically the same but for the igniter configuration. Lot S005 used the standard 3-step configuration and the engineering sample used the 1-step configuration.

The delays successfully completed and passed the safety testing. All the projectiles were ballistically tested without any major incidents although only five of the twelve round tested were in the rocket on configuration.

The twenty rounds ballistically tested again validated the reliability of the single column delay (table 27). The 3-step igniter and the 1-step produced an acceptable standard deviation.

SINGLE COLUMN ENGINEERING VARIATIONS

Column Length

Since the beginning of the investigation various column length were used. The length of the column was varied by controlling the hole depth of the delay housing (table 28).

When evaluating the initial compositions, the 2.74 in. hole housing was used. This exceptionally long column was used because there was no test data on an axially located single column delay using a tungsten content of 42 pbw. After these delays were tested (table 8), the column was reduced as well as the tungsten content to achieve a mean delay time of 16.00 sec.

The new hole depth was changed to 1.74 + .01 and this depth was used until a change in the washer thickness necessitated another change in the hole depth. The column was now changed to 1.80 + .01 in depth.

The change from 1.80 + .01 was a necessary change in the hole depth due to the pyrotechnic composition changing from 47.5 pbw to 49 pbw. The engineering effort had exhausted the supply of 47.5 pbw and instead of manufacturing a new batch the 49 pbw composition would be used. As it turned out, the switch to the higher fuel content composition helped to eliminate the delay inconsistencies. The chart in table 29 shows the available composition length in relation to the hole depth. In the larger diameter delays the column hole remained at 1.80 + .01 but the available composition length was reduced due to the special washers required.

Washer Variation

The original washers for the single column delay were the standard counterbore washers mated with the standard counterbore configuration. The only major variations in the washer were its diameter when the counterbore was not used and its thickness/diameter when the column diameter was increased (table 30).

One novel approach to washer configuration was the use of a two hole washer as was used in the 5/16 and 3/8 in. hole design. The standard hole size in the counterbored and noncounterbored configuration is .090 + .005 but with the larger diameter columns two .090 + .005 holes were employed.

Pyrotechnic Material

As shown in table 4, the delay composition employed by the early M913 delays was essentially the same as the M548 composition. The single column delay composition deviated somewhat from this composition by the increase in fuel content (table 31) as well as the increase in Potassium Perchlorate. The particle size and material specifications are listed in (table 32) as a reference.

One interesting note is that when the dual column delay was under development the Tungsten use was deagglomerated but the single column employed agglomerated.

Igniter Material

In table 4, the igniter for the dual column M913 delay is shown and this igniter used a VAAR content of 1.0 pbw. The single column delay used essentially the same composition but the VAAR content was increased to 2 pbw (table 33). This increase in the VAAR content was precipitated by the fact that the 1 pbw VAAR igniters always showed sign of degradation. The 1 pbw igniters experienced cracking, chipping, and spalling.

Assembly Procedures

The assembly procedures for the single column delay was identical to the duel column delay in pressures and dwell time. Also, the single column used more delay pellets than the other delays. The major elements of the assembly procedure are shown in table 34.

Consolidation Punches

The single column delay employed the standard 3-step consolidation punch configuration. Towards the end of the program a 1-step punch configuration was used (fig. 10). The 1-step configuration was tried in an effort to increase the amount of igniter. From the test data shown in table 26, the use of the 1-step igniter configuration seemed to increase the standard deviation of the -40 test samples; therefore, no advantage was demonstrated.

CONCLUSIONS

The use of a single column pyrotechnic delay proved to be a viable alternative to the dual column designs of the past.

To enhance the reliability and repeatability of the single column design, the fuel content of the delay composition should be greater than 48 pbw.

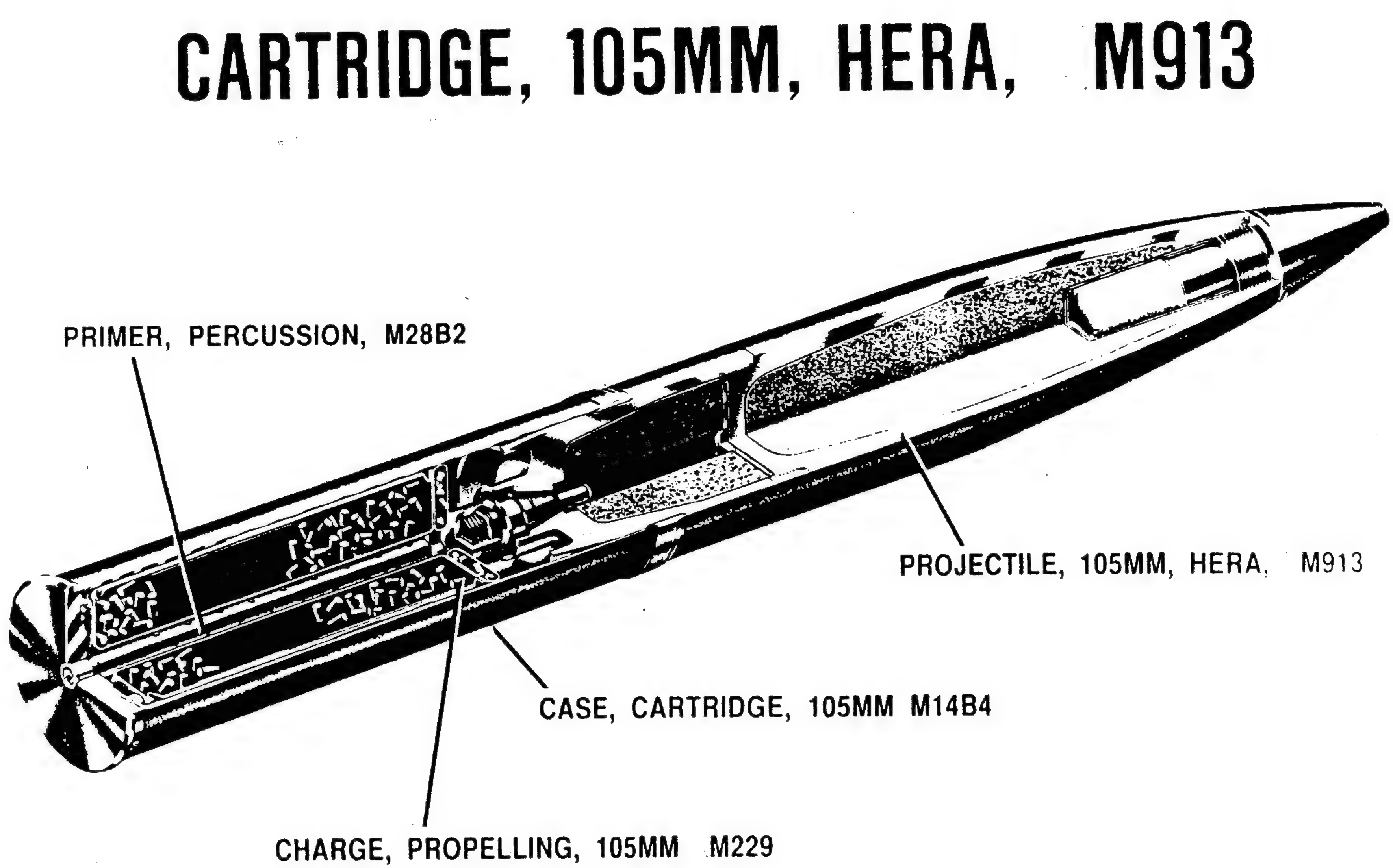


Figure 1
M913 cartridge

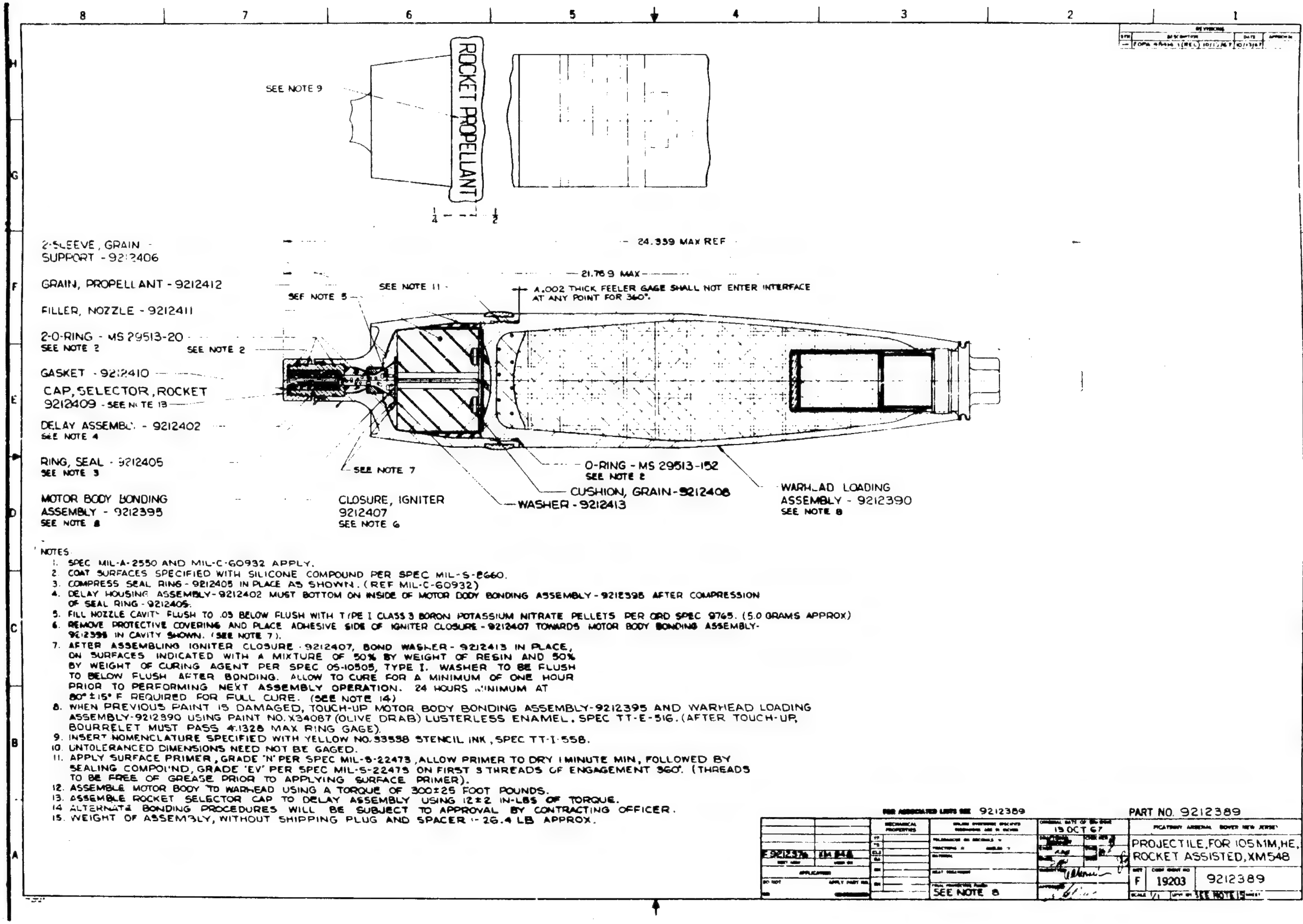


Figure 2
M548 projectile

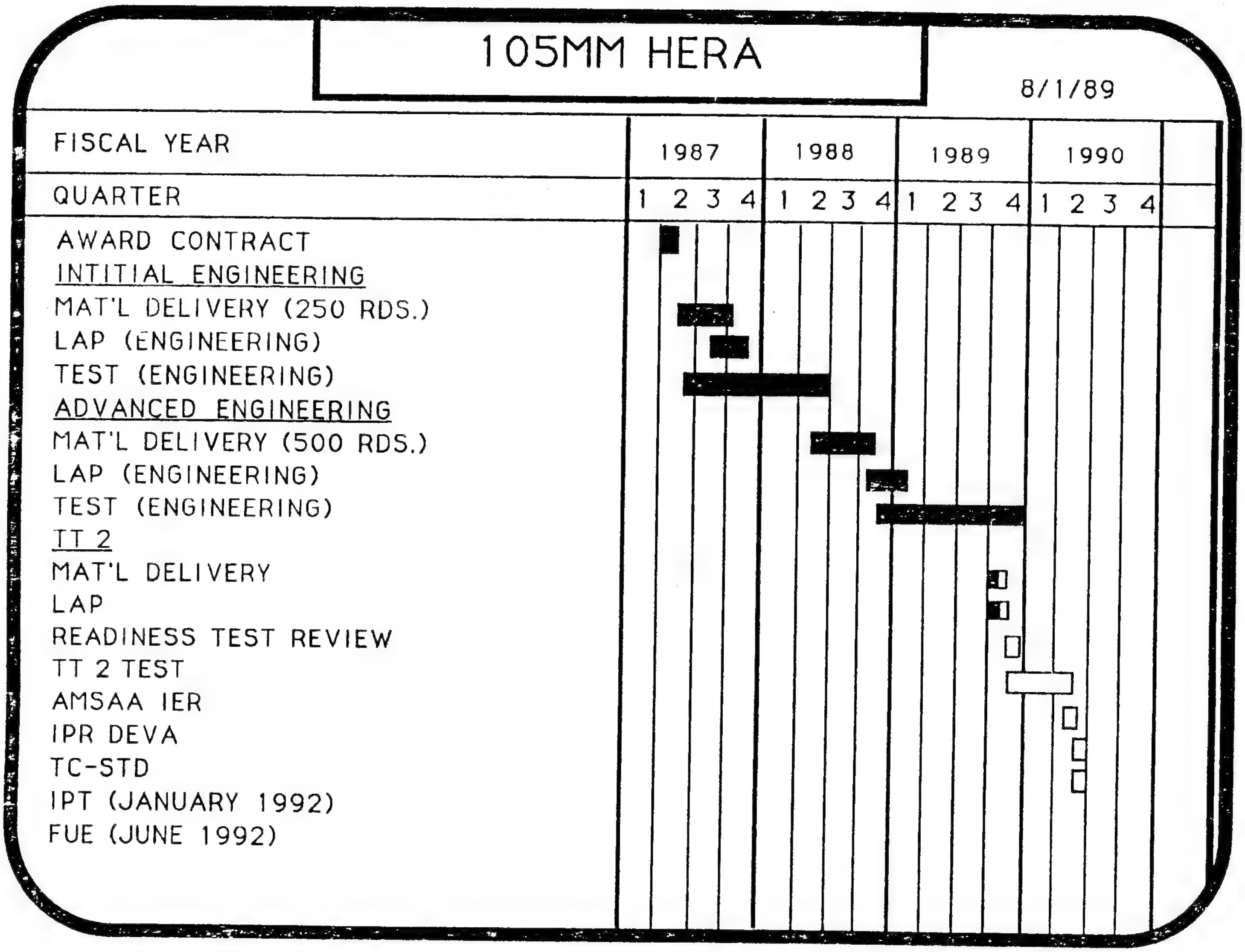
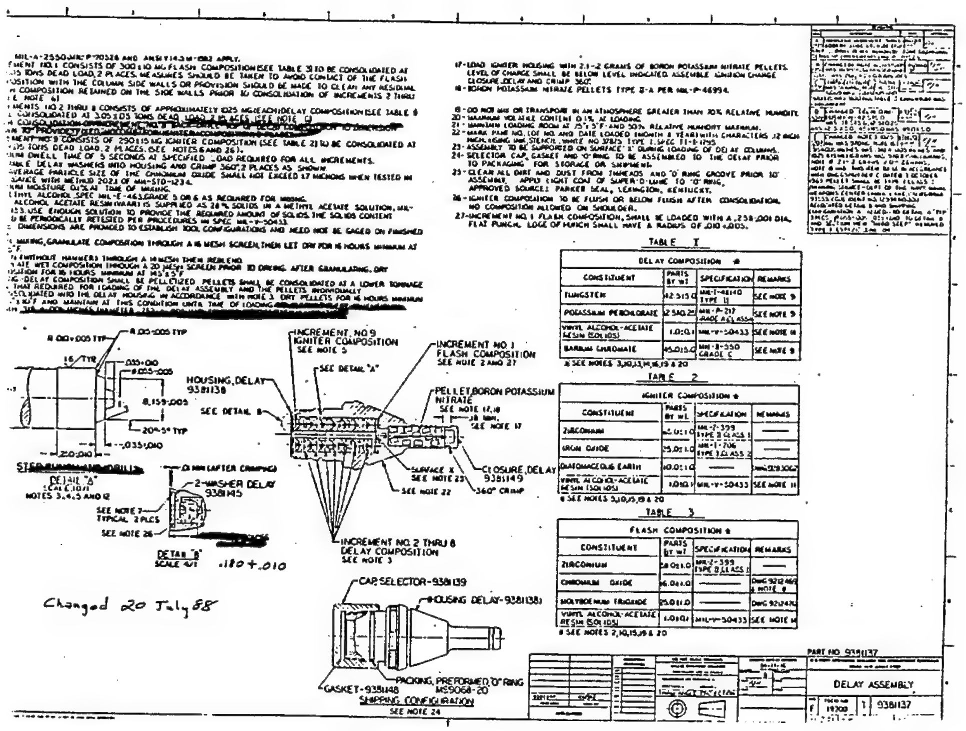


Figure 3
Development phases of M913



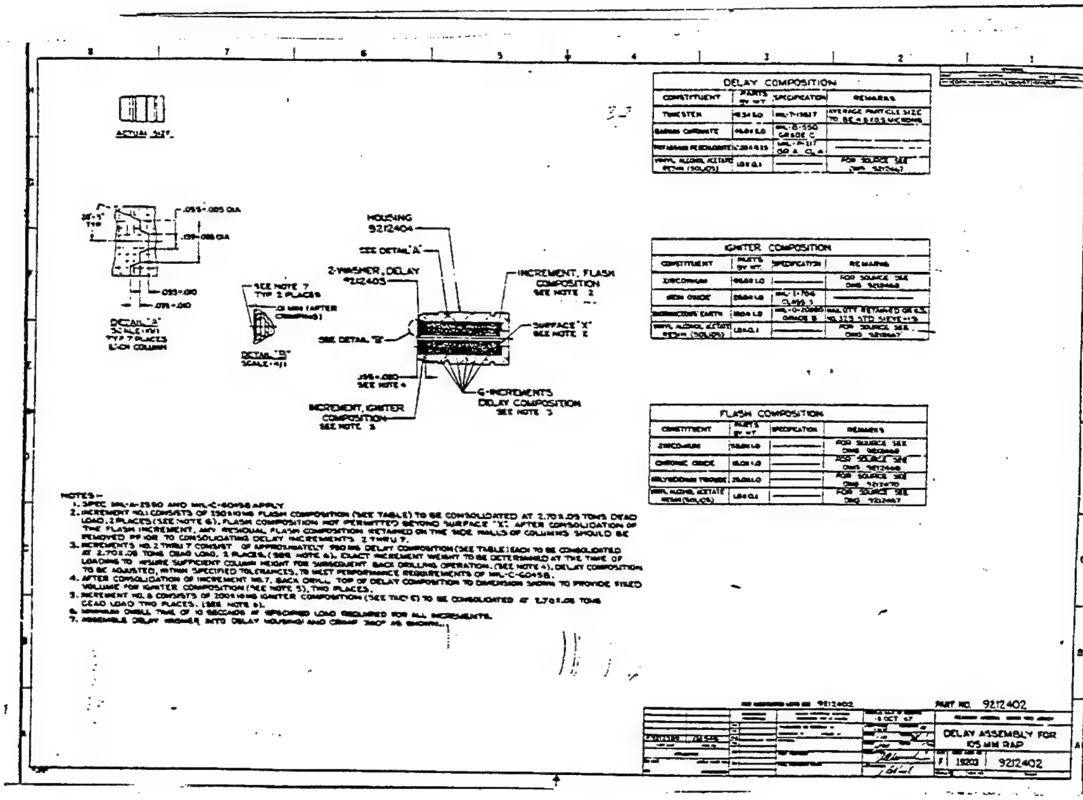


Figure 4
M548 and M913 dual hole delays

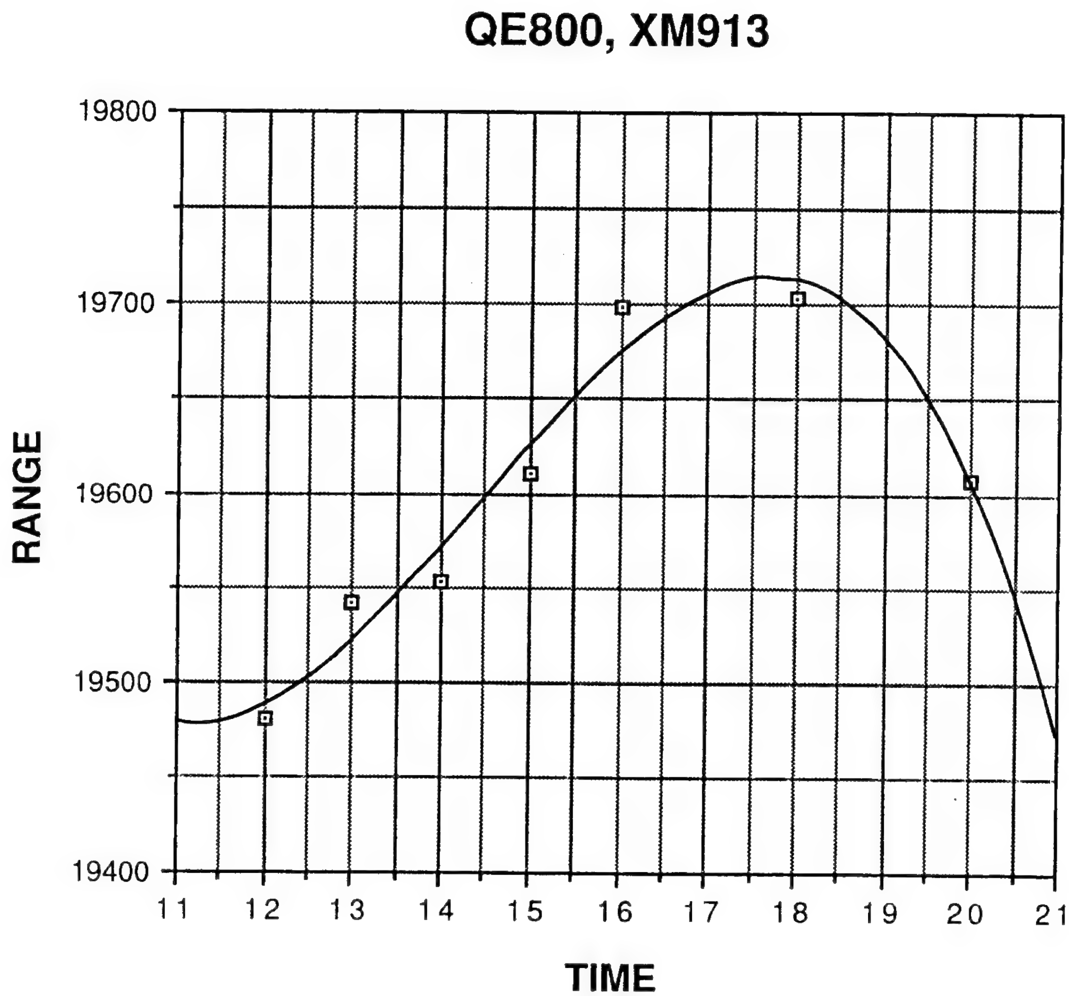


Figure 5
M913/M927 delay time versus maximum range

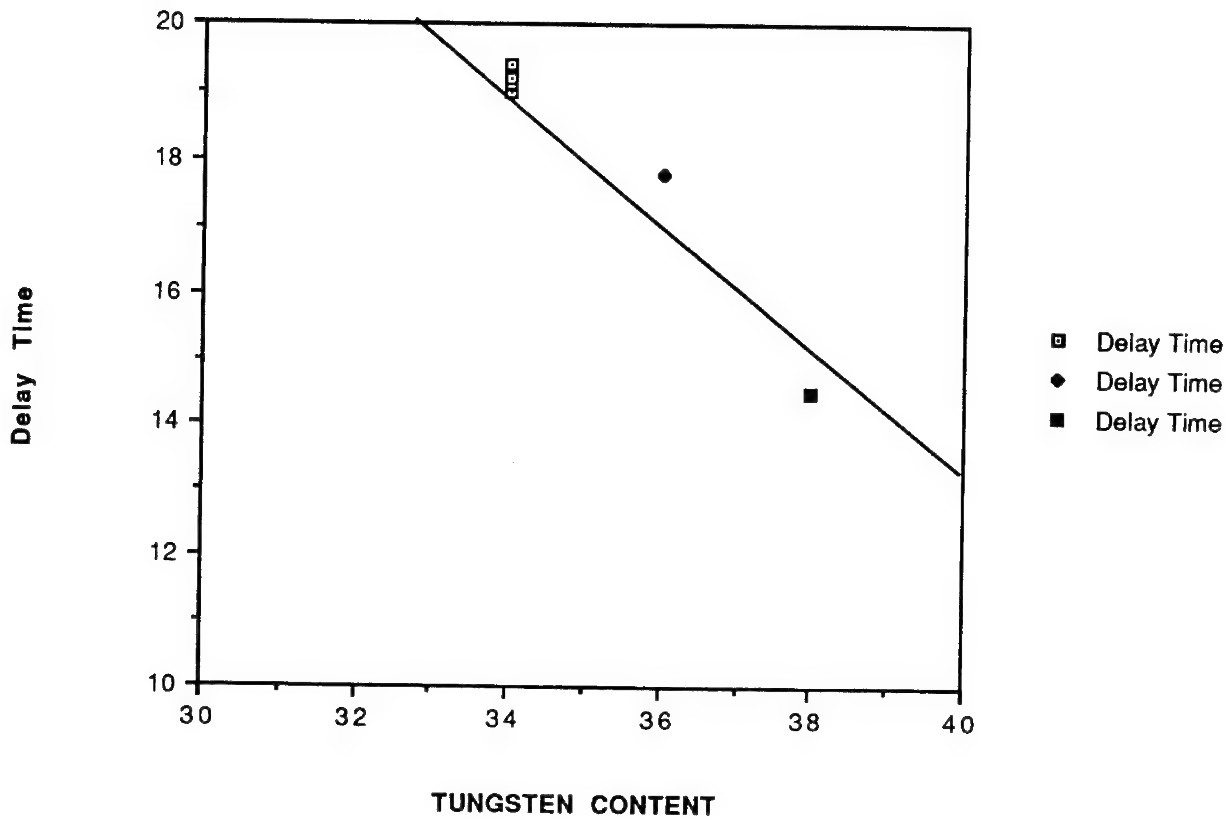


Figure 6
Graph of delay time and tungsten content

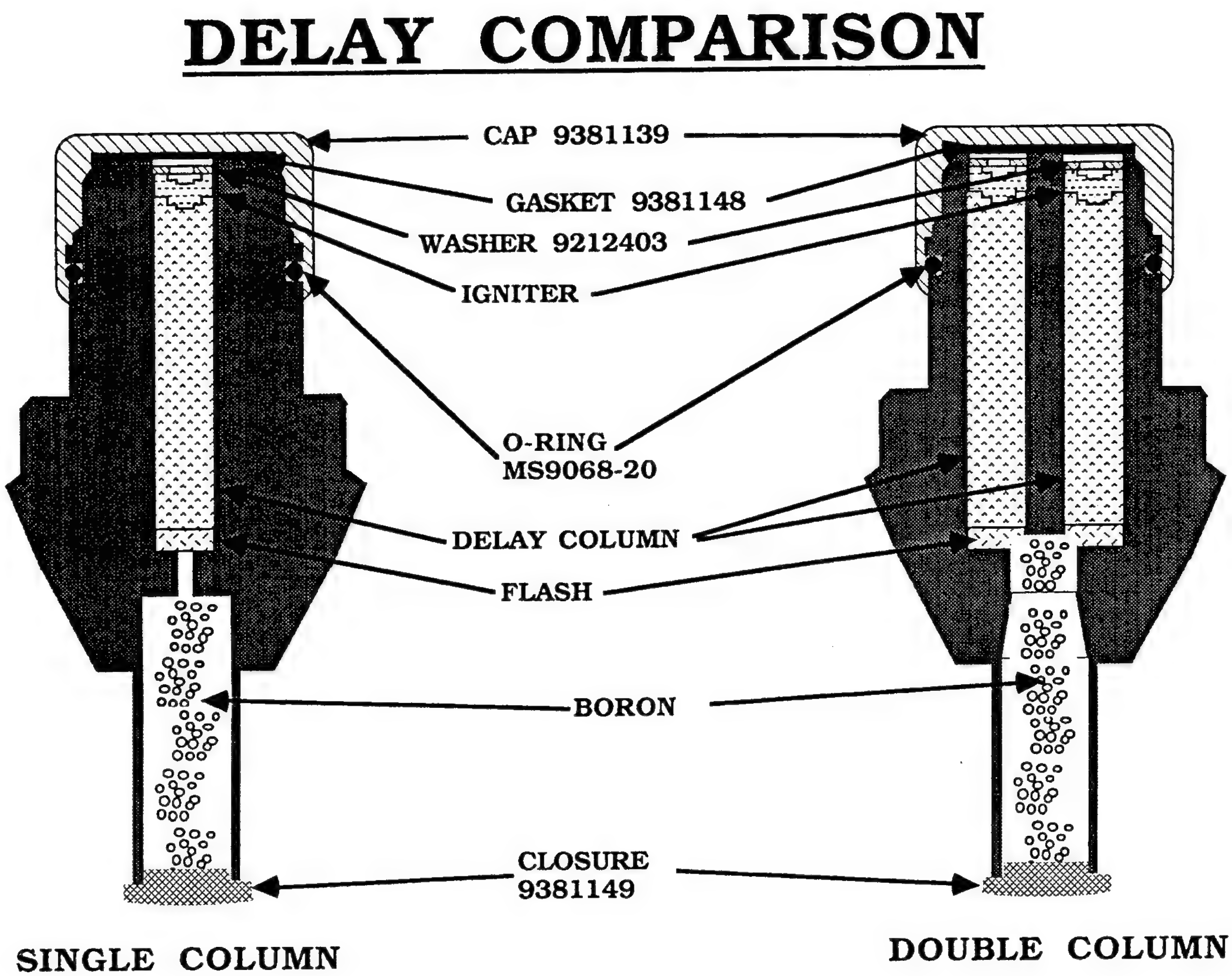


Figure 7
Single hole and dual hole pyro delays

105 MM HERA

M913 PYRO DELAY

W/ COUNTERBORE　　　　W/O COUNTERBORE

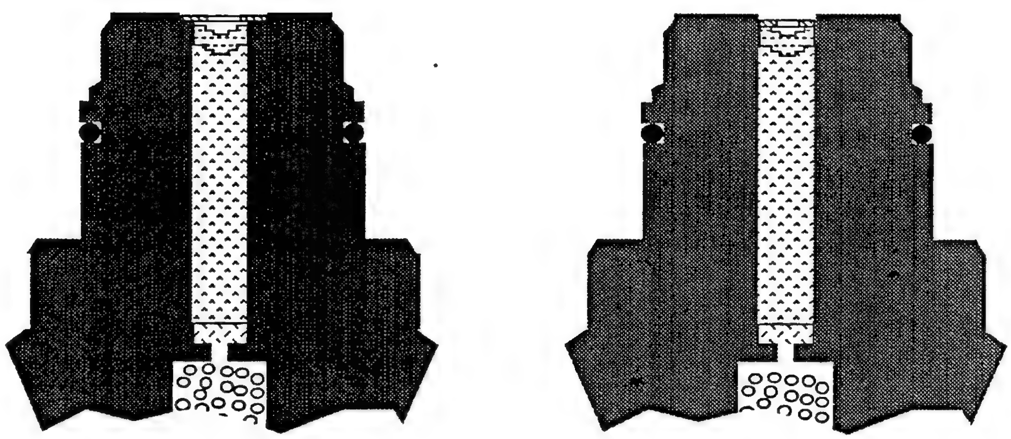


Figure 8
Counterbore versus noncounterbored delay

XM913

M913 PYRO DELAY

W/O COUNTERBORE

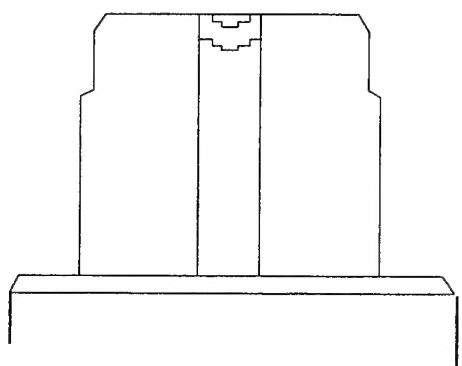


Figure 9
Modified noncounterbored delay

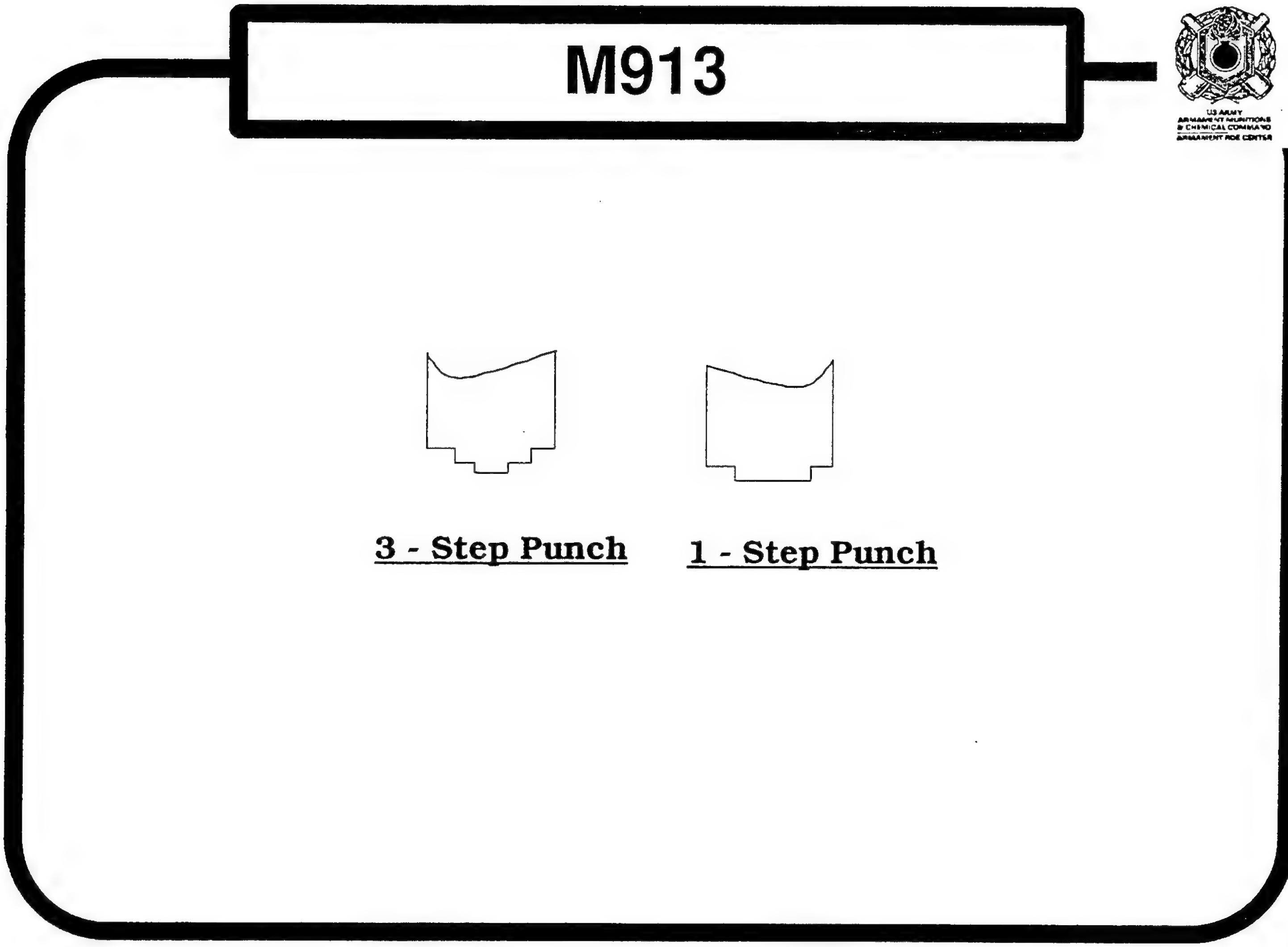


Figure 10
Igniter punch configurations

Table 1
Howitzers

Type	M101	M102	M119
Tube	M2A2	M137	M20A1
Twist type	Constant	Progressive	Progressive
Twist	1/20	1/35 - 1/18	1/35 - 1/18
Travel	78	110	113
Pimp	45,600	45,000	57,000

Table 2
Propelling charges

Type	M67	M229
Zone	1 through 7	8
Weight (lb)	2.825	4.54
Composition	M1	M30

Table 3
Projectile comparison

Type	M760	M548	M913
Projectile weight (lb)	32.0	28.5	33.0
Propelling charge (type)	M200	M176	M229
Muzzle velocity (mps)	616	549	625
Maximum range (m)	14,000	15,000	19,500
Lethality Index	1.0	1.8	1.8
Spin rate (rpm)	20,500	16,000	20,500

Table 4
Delay compositions

Delay composition	**M548**	**M913**
Tungsten	42.5 ± 5.0	42.5 ± 5.0
Potassium perchlorate	12.50 ± 0.25	12.50 ± 0.25
VAAR	1.0 ± 0.1	1.0 ± 0.1
Barium chromate	45.0 ± 5.0	45.0 ± 5.0
Igniter Composition		
Zirconium	65.0 ± 1.0	65.0 ± 1.0
Iron oxide	25.0 ± 1.0	25.0 ± 1.0
Diatomaceous earth	10.0 ± 1.0	10.0 ± 1.0
VAAR	1.0 ± 0.1	1.0 ± 0.1
Flash Composition		
Zirconium	58.0 ± 1.0	58.0 ± 1.0
Chromium oxide	16.0 ± 1.0	16.0 ± 1.0
Molybdenum trioxide	25.0 ± 1.0	25.0 ± 1.0
VAAR	1.0 ± 0.1	1.0 ± 0.1

Table 5
Test data of 28 February 1989

Delay lot number	TDS - 014	TDS - 015	TDS - 016
Tungsten content	34 pbw	38 pbw	36 pbw
Burn time (sec)	19.00	14.50	17.80
	19.10	(15.90)*	17.50
	19.40	13.20	17.60
	19.10	14.00	17.60
	19.20	13.20	17.80
Average time	19.16	13.73	17.66
Standard deviation	0.15	0.64	0.13

*Delay time discounted

Table 6
Test data of 21 April 1989

Delay lot number	TDS - 018
Tungsten content	36.75 pbw
Burn time (sec)	14.00
	13.30
	13.60
	12.40
	12.90
Average time	13.24
Standard deviation	0.62

Table 7
Test data of 30 June 1989

Delay lot number	TDS - 020
Tungsten content	36.75 pbw
Burn time (sec)	11.30
	11.10
	11.30
	10.90
Average time	11.15
Standard deviation	0.19

Table 8
Test data of 12 August 1989

Delay lot number	TDS - 021	TDS - 022	TDS - 023
Tungsten content	31.0 pbw	32.5 pbw	34.0 pbw
Burn time (sec)	25.30	22.90	(17.70)*
	24.80	22.90	19.40
			20.60
			19.20
Average time	25.05	22.90	19.73
Standard deviation	0.35	0.00	0.76

Table 9
Test data of 9 September 1989

Delay lot number	TDS - 024	TDS - 025
Tungsten content	31.0 pbw	32.5 pbw
Burn time (sec)	13.40	(14.20)*
	13.40	17.60
	13.60	17.30
	13.90	18.00
	14.30	17.00
Average time	13.72	17.48
Standard deviation	0.38	0.43

Table 10
Test data of 4 October 1989

Delay lot number		TDS - 027	
Burn time (sec)	14.10	13.50	12.70
	13.90	14.10	13.50
	14.70	13.70	12.50
	14.50	13.10	12.80
	(18.60)*	13.60	13.40
Average time		13.58	
Standard deviation		0.65	

Table 11
Pellet mixtures

Delay hole depth	1.7 in.
Flash increment	0.08 in.
Igniter increment	0.18 in.
Column length	1.44 in.
36.0 pbw composition	0.479 in.
35.1 pbw composition	0.961 in.

*Delay time discounted

Table 12
Test data of 7 November 1989

Delay lot number	TDS - 028	TDS - 029
Tungsten content	MIX	35.20
Burn time (sec)	16.00	16.30
	15.60	15.80
	16.50	(17.80)*
	16.80	16.70
	15.80	16.50
Average time	16.14	16.33
Standard deviation	0.50	0.37

*Delay time discounted

Table 13
Dual versus single comparisons

	Dual hole	Single hole
Number columns	2	1
Diameter	0.25 in.	0.25 in.
Column Depth	1.70 in.	variable
Flash	600.00 mg	300.00 mg
Flash length	0.08 in	0.08 in
Composition	10,800.00 mg	variable
Composition length	1.44 in.	variable
Ignitor	580.00 mg	290 mg
Ignitor length	0.18 in.	0.18 in.

Table 14
Test data of 9 March 1990

Delay lot number	E001/E002
Tungsten content	42 pbw
Burn time (sec)	28.70
	31.30
Average time	30.01
Standard deviation	1.86

Table 15
Test data of 31 March 1990

Delay lot number	E003/E004
Tungsten content	48 pbw
Burn time (sec)	27.10
	26.90
Average time	27.00
Standard deviation	0.14

Table 16
Test data of 10 May 1990

Delay lot number	E005 - E009
Tungsten content	47.5 pbw
Burn time (sec)	15.90
	15.60
	15.90
	16.10
	15.90
Average time	15.87
Standard deviation	0.18

Table 17
Consolidation pressures

	0.25 Ø	0.313 Ø	0.375 Ø
Composition			
Load	6,000 lb/f	8,200 lb/f	12,000 lb/f
Pressure	105,634psi	105,634 psi	105,634 psi
Flash			
Load	2,000 lb/f	2,800 lbf	4,000 lbf
Pressure	35,212 psi	35,212 psi	35,212 psi

Table 18
Test data of 21 June 1990

Delay lot #	E11	E12	E10
Tungsten content	47.5 pbw	49.0 pbw	47.5 pbw
Hole diameter	0.313	0.313	0.375
Burn time (sec)	14.00	13.50	12.50
	14.20	13.60	10.30
	14.40	13.80	11.10
	14.10	12.60	13.50
		12.90	12.10
Average time	14.18	13.28	11.89
Standard deviation	0.17	0.51	1.24

Table 19
Test data of 26-27 July 1990

Date tested	32714	32715
Delay lot number	S001	S001
Tungsten content	47.5 pbw	47.5 pbw
Burn time (sec)	16.35	15.40
	15.90	16.20
	16.10	15.60
	15.35	15.90
	18.90	15.90
	14.10	15.80
	15.80	15.00
	15.95	16.10
	16.25	15.95
	16.10	
Average time	16.08	15.76
Standard deviation	1.185	0.37

Table 20
Test data of 1 August 1990

Test temperature	145°F	50
Delay lot number	S001	S001
Tungsten content	47.5 pbw	47.5 pbw
Burn time (sec)	15.60	19.30
	15.20	17.40
	14.70	17.20
	14.80	21.80
	15.20	17.45
	15.20	17.20
	15.00	17.80
	15.00	17.30
	15.00	17.30
Average time	15.10	18.05
Standard deviation	0.26	1.46

Table 21
Firing table data

Group no.	Samples	QE	Temperature (°F)	Burn time	Std. dev.
55	5	500	70	15.84	0.35
57	5	750	70	15.90	0.00
59	5	950	70	15.86	0.09
54	5	1150	70	16.44	1.22
56	8	1150	70	16.08	0.86
63	5	500	70	15.86	0.87
67	5	950	70	15.48	0.42
65	5	750	70	15.62	0.16
40	5	750	120	15.16	0.13
	5	750	70	15.62	0.25
	5	750	20	16.86	0.78
	5	750	-40	19.66	1.81
62	5	300	70	15.56	0.09
64	5	750	70	16.16	1.03
66	5	750	70	16.08	0.69
68	5	950	70	15.78	0.13
58	5	750	70	16.06	0.31
39	5	750	120	15.22	0.15
	5	750	70	15.80	0.16
	5	750	20	17.70	1.72
	5	750	-40	18.76	2.28
60	5	1150	70	15.74	0.17
56	5	1150	70	15.78	0.15
53	5	300	70	15.96	1.04
61	5	300	70	15.62	0.08
40	5	750	-40	16.62	0.19
39	5	750	-40	19.04	1.41

Table 22
Single column configurations

Lot number	Counterbore	Tungsten	Igniter
TAC906002S002	No	47.5 pbw	2 pbw 3-step
TAC90H002S003	No	49.0 pbw	2 pbw 3-step
TAC90H002S004*	Yes	49.0 pbw	2 pbw 3-step
TAC90H002S005*	Yes	49.0 pbw	2 pbw 3-step
Engineering samples	Yes	49.0 pbw	2 pbw 1-step

*A sample of four delays from each group was assembled without a washer.

Table 23
Test data of 25 August 1990

Test temperature	70°F	-40°F	70°F	-40°F
Delay lot number	S003	S003	S004	S004
Counterbore	No	No	Yes	Yes
Burn time (sec)	16.2	18.3	NF	NF
		17.8	18.3	
		17.6		NF

Note: NF= No function

Table 24
Test data of lot S002

Projectile	M927	M913
Test sequence	5 g	Group 53
Test temperature	70°F	70°F
Burn time (sec)		
	17.10	15.60
	16.80	15.60
	17.10	17.80
	17.10	
	16.70	
	16.90	
	17.20	
	17.00	
	16.90	
	17.20	
Average time	17.00	
Standard deviation	0.17	

Table 25
Test data of lot S003

Test sequence	4 A	3 A-1	3 A-2
Test temperature	-40°F	70°F	70°F
Burn time (sec)	17.20	16.10	16.00
	-.-	16.00	19.20
	17.10	15.30	16.00
	16.90	15.60	15.70
	17.10	15.50	15.60
Average time	17.08	15.70	16.50
Standard deviation	0.13	0.34	1.52

Table 26
Test data of lot S004

Test sequence	4 B	3 B
Test temperature	-40°F	70°F
Burn time (sec)		
	17.00	15.70
	17.50	15.40
	17.00	16.10
	16.90	15.50
	17.30	16.00
		16.00
		16.30
		15.40
		15.40
		15.70
Average time	17.14	15.75
Standard deviation	0.25	0.33

Table 27
Test data of 19 September 1990

Test temperature	-40°F	70°F	-40°F	-40°F
Delay lot number	S005	ES	S005	ES
Burn time (sec)				
	17.10	16.00	17.40	17.10
	16.90	15.90	16.90	21.90
	16.80	15.50	16.50	16.90
	16.80	15.30	16.80	16.80
	16.80	14.90	16.90	17.10
Average time	16.88	15.52	16.90	17.96
Standard deviation	0.13	0.45	0.32	2.21

Table 28
Delay column variations

Drawing number	Revision	Hole depth	Hole diameter
SK - MGH - 10473	—	2.74 + 0.01	0.266 + 0.003
SK - MGH - 10473	A	1.74 + 0.01	0.266 + 0.003
SK - MGH - 10473	B	1.80 + 0.01	0.266 + 0.003
SK - MGH - 10473	C	1.90 + 0.01	0.266 + 0.003
129129177	—	1.80 + 0.01	0.266 + 0.003
SK - MGH - 10486	—	1.80 + 0.01	0.311 + 0.003
SK - MGH - 10476	—	1.80 + 0.01	0.374 + 0.003

Table 29
Composition length

Hole depth	Composition depth
2.74 + .01	2.47
1.74 + .01	1.47
1.80 + .01	1.53
1.90 + .01	1.63

*The flash increment occupies .08 in., the igniter increment occupies .19 in.

Table 30
Washer variations

Column Diameter	Washer		Counterbore	
	Diameter	Thickness	Diameter	Depth
0.266 + 0.003	0.319 - 0.003	0.036 - 0.004	0.346 + 0.003	0.047 + 0.005
0.266 + 0.003	0.265 - 0.003	0.032 ± 0.002	No counterbore	
0.266 + 0.003	0.345 - 0.005	0.037 - 0.010	0.346 + 0.003	0.060 + 0.005
0.311 & 0.374 + 0.003	0.534 - 0.005	0.087 - 0.010	0.535 + 0.003	0.117 + 0.005

Table 31
Single column composition

Delay composition	Pbw
Tungsten	49.0
Potassium perchlorate	14.5
VAAR	1.0
Barium chromate	36.5

Table 32
Single column composition specifications

Ingredient	Lot number	Specification	Particle size
Tungsten	WA435537C	MIL - T - 481 40 (agglomerated)	10
Potassium perchlorate	15138	MIL - P - 217 (grade A, class 4)	20
VAAR	30	MIL - V - 50433	
Barium chromate	21283	MIL - B - 550 (grade C)	

Note: Particle size is in microns.

Table 33
Single column igniter

Ingredient	Pbw
Zirconium	65
Iron oxide	25
Diatomaceous earth	10
VAAR	2

Table 34
Assembly procedure

Process:

Load Flash Powder	300 mg 2100 - 2200 lb/f load 5.0 - 6.0 sec dwell Flat punch
Load Delay Pellets	900 - 1000 mg pellets 9 pellets total 6000 - 6200 lbf load (each pellet) 5.0 - 6.0 sec dwell 3-step punch Back drill 0.18 - 0.19 in.
Load Igniter Powder	290 mg 6000 - 6200 lb/f load 5.0 - 6.0 sec dwell 3-step punch or 1-step punch

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